INCENTIVES TO CONSERVE WATER IN AGRICULTURE

A Cooperative Demonstration Program

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THIRD ANNUAL REPORT

Challenge Grant Program:

COLLABORATIVE FIELD DEMONSTRATIONS OF THE EFFICACY AND PRACTICALITY OF

FINANCIAL INCENTIVES FOR AGRICULTURAL WATER CONSERVATION

January to December 1996

Submitted to

U. S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
2800 Cottage Way
Sacramento, CA 95825-1898

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ANNUAL REPORT

FINANCIAL INCENTIVES FOR AGRICULTURAL WATER CONSERVATION CHALLENGE GRANT

Table of Contents

C-097446

I. Executive Summary

This Annual Report describes activities undertaken during 1996 as part of the Financial Incentives for Agricultural Water Conservation Challenge Grant awarded to the Natural Heritage Institute (NHI). NHI and its collaborators—the Berkeley, Davis, and Riverside campuses of the University of California, the California Department of Water Resources, Westlands Water District, and Arvin-Edison Water Storage District—have designed innovative water pricing and delivery policies to be implemented and evaluated at Westlands and Arvin-Edison during the ensuing growing seasons. The primary goal of these policy reforms is to encourage conservation of irrigation water without dictating the use of the conserved water. The project also supports basic research on water use decision making at the farm level to assist in developing water pricing and delivery policies in the other Reclamation areas. The major achievements of the project during 1996 are described in this Report.

Westlands Water District

On March 1, 1996, we launched the Westlands WaterLink program. The goal of WaterLink is to reduce the search and transaction costs associated with water trading. This computerized trading scheme is the first of its kind anywhere. Several training sessions were held at the district office and over 30 growers initiated the WaterLink program. Since then, we have purchased additional site licenses to increase our capacity to 100 accounts. Considerable effort was also expended in training the Westlands staff on the operation of the system. Growers use WaterLink to trade water and improve management of their own supplies. Farms can also use WaterLink to schedule water deliveries, and soon they may be able to use it to obtain water account balances much like one obtains a bank account balance at an ATM. Currently, WaterLink is only used in Westlands, but in the future it may link farms in Westlands with farms in other districts. We are currently negotiating with the San Luis-Delta Mendota Authority to expand WaterLink to its entire membership.

C-097447

Analysis of past trading patterns continued during the year. This analysis, along with information concerning WaterLink, is summarized in an upcoming article in *Choices*.

Arvin-Edison Water Storage District

In the spring of 1995, after coordinating with the Challenge Grant project members, the District changed its rate. To date, the project team has only been able to assess the impact of the rate change using data for 1995, although 1996 data should soon be available. However, the 1995 data look promising; there was a 1,200-acre reduction in hay and a 900-acre reduction in small grains, both of which tend to be low-value cover crops. There was also an 800-acre increase in potatoes, a 400-acre increase in onions, and a 500-acre increase in miscellaneous truck crops, all of which are considered high- to medium-value crops. The end result is a slight increase in water use and a dramatic increase in the value per acre-foot of water applied.

The Challenge Grant project members focused their research efforts on three areas of study. First, with the assistance of the Arvin-Edison Water Storage District (the District), they completed three studies investigating the determinants of irrigation technology choice. The general conclusion of the irrigation technology adoption studies is that water price is not always the most important determinant of irrigation technology choice. Though water price is important, soil characteristics and crop type have a larger influence on the type of irrigation technology adopted in the district. The response to increases in water price varies by crop. For example, the project team found that, while increases in water price encouraged adoption on citrus crops, it did not have a significant impact on vineyard crops. At higher initial water price levels, the effectiveness of an increase in water price as an incentive for conservation decreases. That is, if you increase the water price from $30 to $50 per acre-foot, you will get a larger response than when you raise it from $50 to $70 per acre-foot.

C-097448

Applications and Implications for Designing Financial Incentives

A major emphasis of the basic research component of the Challenge Grant project was to investigate the mechanisms of reform towards more efficient water resource allocation. One study evaluates alternative mechanisms for transformation from a traditional allocation system, characterized by distribution of water to users according to historical rights at relatively low prices, to a more efficient water allocation system. Under efficient water pricing, users make decisions that take into account the real social price of water. Implementation of such a system at the district level requires recognizing the balanced budget constraint facing water districts and incorporating equity considerations.

One method that attains efficiency while meeting budget and efficiency constraints is a transferable water rights systems. Under this system, each water user is allocated individual water rights in proportion to his/her historical rights and pays for this water according to an average pricing rule, but then users are allowed to trade among themselves. An alternative system that will result in a desirable outcome is passive market (buy-back). The district purchases an optimal aggregate amount of water; then farmers are allotted an initial amount which is proportional to their historical use and they pay the average cost for this initial amount. Farmers can adjust their water consumption by buying or selling water to the district at the real price of the water. On the other hand, we find that block (tiered) pricing may not lead to efficient resource allocation, especially where there is significant heterogeneity of water users and some of them are very inefficient.

Another study compares the evolution of water marketing in the Central Valley Project in California with water marketing in the Big Thompson Project in Colorado. The paper argues that institutional barriers in the CVP still prevent many water trades from occurring and increase the cost of trades which do occur. As a result, actual water market activity is still limited. In contrast to the CVP, active water markets between agricultural and urban areas have developed in Colorado's Big Thompson Project. There are both long-term sales of water rights and short-term water rental transactions. Differences in preexisting property rights and organizational structures explain differences in water trading patterns. Thus, there is no unique way to reform water systems and achieve efficiency. Past choices and the need to obtain consensus at the present will lead each region to develop its own unique set of institutional reforms that improve water use efficiency.

A third study investigates the effects of water markets on irrigation technology adoption. It argues that adoption of irrigation technology is an irreversible choice made under conditions of uncertainty and argues that, while in some cases introduction of markets will increase the adoption of irrigation technology, in others the extra flexibility provided by markets may actually reduce a likelihood of technology adoption. The exact impact of water markets on technology choice depends on the heterogeneity among users and the seniority of water rights to farmers under the prior appropriation system. We intend to expand the model and use it to simulate Central Valley data in the coming year.

II. Westlands Water District

Local water markets have been active for years in agricultural water districts throughout the west. Inter-sector water markets, in which long-term water rights are actually bought and sold, have been slower to develop. Despite the potential gains from trade, there are real obstacles which need to be addressed before greater market adoption will be feasible. In addition to physical, institutional, and legal obstacles, market participants may face high transaction costs associated with finding potential trading partners, negotiating deals, and obtaining bureaucratic approval.

The most active local water market in the Central Valley Project (CVP) is in the Westlands Water District. Westlands is the largest district in the CVP, with approximately 600 farms covering nearly 600,000 acres. Due to its size, the relative scarcity of water, and the existence of farm heterogeneity, there are significant opportunities for trade in Westlands. However, even though the market in Westlands is relatively active, market participants may still face high transaction costs. Unlike most markets, the water market in Westlands has no centralized trading location and no publicly posted market price. To avoid the search and negotiation costs associated with trading in this environment, farms often make supply adjustments by transferring water internally within farm management units instead of in the market. These internal transfers are analogous to movements of inputs between factories within the same firm. If farms do trade in the market, they tend to trade in networks in which they trade repeatedly with a core group of farms. The market in Westlands provides evidence that transaction costs can have a significant impact on market participation rates and trading patterns.

On March 1, 1996, we launched the Westlands WaterLink program. The goal of WaterLink is to reduce the search and transaction costs associated with participation in the market. This computerized trading scheme is the first of its kind anywhere. Several training sessions were held at the district office and over 30 growers initiated the WaterLink program. Since then, we have purchased additional site licenses to increase our capacity to

100 accounts. Considerable effort was also expended in training the Westlands staff on the operation of the system. Growers use WaterLink to trade water and improve management of their own supplies. Growers can post "water wanted" and "water for sale" ads, negotiate with other farms and the water district via email, check on the weather, and view district reports (see 1995 annual report for more information concerning the capabilities of WaterLink). Farms can also use WaterLink to schedule water deliveries, and soon they may be able to use it to obtain water account balances much like one obtains a bank account balance at an ATM. By making this information more readily available, growers will be able to better manage their irrigation systems throughout the season.

As with other network technologies, the value of WaterLink will increase as the number of users increases. Currently, WaterLink is only used in Westlands, but in the future it may link farms in Westlands with farms in other districts. In addition to the benefits to water users, the data generated by WaterLink will provide policy-makers with valuable information about water markets which can be used to design institutions to facilitate trading. At the moment, most water trades will continue to be short-term local transactions; however, in the future, as water becomes more scarce, there will be greater incentives to invest in the physical structures and institutions which can make long-term, inter-sector markets and options markets possible.

Analysis of past trading patterns continued during the year. This analysis, along with information concerning WaterLink, is summarized in an upcoming article in *Choices* (see Appendix 4). Descriptions of trading activity and trading patterns are helpful in assessing the performance of the market and in determining areas for improvement. Presentations on WaterLink were made to several professional meetings as well as to local groups (Colorado Water Workshop, Gunnison, Colorado, July, 1996; California Department of Water Resources, March, 1997; California Cooperative Extension Specialists and Advisors, May, 1996; and Great Decisions Debate, March, 1996). Interest in WaterLink from Westlands' growers has increased. In late 1996, additional site licenses were purchased to allow more growers to have accounts on the system.

WaterLink activity was intense at the beginning of 1997. As winter storms filled California's reservoirs, growers within the district realized that they would not be allowed to carry over water and they would probably have sufficient supplies for the upcoming year. Thus, by February, 1997, there were more than 24 water-for-sale posts on the system, representing over 25,000 acre-feet of water. This activity shows that growers know the system is available and that they will try to use it when the need arises. Unfortunately in this case, there were not many willing buyers as all growers in the district were in the same situation.

The level of activity does demonstrate what could happen in a drought year. In the above case, there were few, if any, trades because the price of water to be paid to the district hit an artificial lower bound, the costs to be paid to the district. Growers had all of the water they wanted at this low cost, and it was not in anyone's best interest to pay growers to take the water. In case of a drought, there would be no artificial limit on price. Growers could negotiate prices upward to a market-clearing level.

One way to improve the efficiency gains from marketing is to expand the market so that participating members come from more diverse water supply situations. We are currently negotiating with the San Luis-Delta Mendota Authority to expand WaterLink to its entire membership. If this were to take place, we will be more likely to create a market where some growers have excess water and others are in need at the same time. The Authority has given preliminary approval to implement the market but has not yet been able to allocate the necessary start-up funds. We will continue to work with the Authority and hope to have the areawide market in operation by March, 1998.

The introduction of a multitude of water district computerized markets will be a great challenge both operationally and conceptually. New markets will require a much more complex computer network that will enable a fast exchange of information and coordination between districts and growers. The expanded market may also raise problems in conveyance of water between locations. We can identify several situations that may need to be addressed structurally over time. Considerable programming needs to be performed to implement these plans. This type of system will create new procedures for communication and interaction among growers, districts, and the Bureau. The expansion of our experiment into several districts is essential for using market incentives as a mechanism to achieve conservation and efficiency in water resource use in California.

As we go forward in expanding the market and taking advantage of its potential, we have to recognize two important issues that have to be addressed both in our research and which may later be incorporated in the market design. These issues are water management and drainage. We will need better monitoring and understanding of the impact of the introduction of water trading on ground water reservoir, and that may lead to the introduction of procedures that may control against excessive ground water pumping, especially in situations where several growers or districts share the same ground water aquifer. Drainage issues are very important for some growers in Westlands and in other regions of the Central Valley and, as Dinar and Zilberman suggest, trading in water will affect the drainage problem. Thus, some investigation of the impact of trading on drainage will be important in assessing the impacts of the introduction of the water markets in the Central Valley. Furthermore, the drainage problem may be better controlled by introducing some mechanisms to trade in drainage rights and complementing the water markets with the market for tradable permits in drainage. We will continue to investigate this possibility as we move forward.

III. Arvin-Edison Water Storage District

A. Pricing and Delivery Policy Reforms

In the spring of 1995, the District changed its rate structure, based on contracted water allotments, to changes strictly based upon quantities used. Historically each grower

C-097454

had been contracted a given allotment of water per acre. If growers needed more, they would either pump ground water or purchase additional water from the District when it was available. With the change in the rate structure, growers are no longer limited to a specific quantity of water, however, the variable portion of the charge has been increased to discourage excessive water use. One of the specific goals of this policy change was to target some water uses that the District thought were wasteful, especially preirrigation and other year-end irrigation activities.

The problem was that, when growers had water left over at the end of the year under the water contract rate structure, they would typically use it on low-value cover crops, such as hay, or use it for preirrigation. This typically was not an efficient use of water, but the grower perceived the water as already being paid for since it was specified in the contract. These changes have removed the perception that the water is already paid for and increased year-end flexibility.

To date, the project team has only been able to examine data for 1995, although 1996 data should soon be available. However, the 1995 data look promising; there was a 1,200-acre reduction in hay and a 900-acre reduction in small grains, both of which tend to be low-value cover crops. There was also an 800-acre increase in potatoes, a 400-acre increase in onions, and a 500-acre increase in miscellaneous truck crops, all of which are considered high- to medium-value crops. The end result is a slight increase in water use and a dramatic increase in the value per acre-foot of water applied.

During most of 1996, the project team and the District had been discussing research topics to undertake in the second phase of the cooperative demonstration project. A consensus was reached to investigate a number of interesting issues related to rate setting: continued study of the changes made to District water contracts; how to set drought-contingent tiered pricing; how to incorporate information on the price elasticity of water in determining the optimal fixed and variable components of the rate structure; empirically justifying a differential GA and GP service charge for ground and surface water users; and the study of volumetric ground water charges and tiered pricing.

B. Basic Research

The Challenge Grant project members focused their research efforts on three areas of study. First, with the assistance of the Arvin-Edison Water Storage District (the District), they completed three studies investigating the determinants of irrigation technology choice. Two of these studies were published in professional journals (Appendices 5 and 6), while the third has been submitted for publication. Second, the project team has continued to study modifications made to the District water contracts in earlier stages of the project. Though sufficient data are not yet available to statistically test for changes in water use as a result of the contract changes, the existing data are promising. Third, the project team members have coordinated with the District to identify and initiate studies for the second phase of the cooperative demonstration project.

The general conclusion of the irrigation technology adoption studies is that water price is not the most important determinant of irrigation technology choice. Though water price is important, soil characteristics and crop type have a larger influence on the type of irrigation technology adopted. With respect to the District, increases in water price will not generate a large amount of water conservation because the price is already high and there has already been a substantial amount of technology adoption (the distribution is 25 percent furrow/flood, 50 percent sprinkler, and 25 percent drip). However, implications are that, in a water district with a lower cost price, similar crops, and land quality, changes in water price could be an effective tool to encourage water conservation.

There are some caveats to using water price as means to encouraging water conservation. First, the response to increases in water price varies by crop. For example, the project team found that, while increases in water price encouraged technology adoption on citrus crops, it did not have a significant impact on vineyard crops. This is primarily due to physiological characteristics of vines—the root structure is not as stable under drip irrigation. The different effects of water price and field characteristics on technology choice for different crops are important to consider when designing a water pricing policy. Study results show that a poorly designed water policy could result in a large profit loss to growers and only a modest level of water conservation.

Second, as water price increases, the response becomes more inelastic. That is, if you increase the water price from $30 to $50 per acre-foot, you will get a larger response than when you raise it from $50 to $70 per acre-foot. This is because at lower price levels water is used less efficiently so it is easier to respond to price changes. As price increases, growers become more efficient and each new unit of savings becomes more costly. A third caveat is that growers face binding financial, time, and human capital constraints that will limit their ability to respond to changes in water price. This was made clear during the in-person interviews. Often a price change will make a grower want to conserve water, but other constraints, such as financing a new irrigation system, may cause them to delay changes. Consequently, there may be a lag time before growers respond to a change in a water pricing policy.

IV. Applications and Implications for Designing Financial Incentives

Allocation and Pricing at the Water District Level

Increased water scarcity is a global water phenomenon, and throughout the world water resource managers are considering alternative mechanisms for increasing the efficiency of water resource allocation. The paper by Brill, Hochman, and Zilberman provides a general framework to consider alternative mechanisms for transformation from a traditional allocation system, characterized by distribution of water to users according to their historical water rights at relatively low prices, to a more efficient water allocation system. The framework recognizes the balanced budget constraints facing water districts and aims to align the public and private costs of water use. The framework identifies alternative water allocation mechanisms (active versus passive trading) that may lead to efficiency and compares the performance according to information requirements and difficulty of implementation. The paper shows that these mechanisms are superior to block pricing.

Some of the literature on water pricing (Burness and Quirk; Gisser and Sanchez; Gisser and Johnson; Howe, Schurmeier, and Douglas; Tsur and Dinar; Zilberman and Shah; and Chakravorty, Hochman, and Zilberman) recognized the suboptimality of a traditional water rights system and recommended transition to market-like allocation of water, although the analyses did not include a revenue constraint relevant to nonprofit nature water agencies.

The paper argues that, under traditional water allocation systems, the water agencies set the price that satisfies farmer demand and balances the water agency budget. This results in a system of average cost pricing. The amount the user pays for each unit of water equals the average cost of conveyance of the water rather than the opportunity cost of the water (the value of the water in alternative use). It is almost trivial to say that this type of policy results in inefficient resource allocation, namely an excessive use of water above the social optimum.

Now, suppose that increased water scarcity leads to a water reform that aims to achieve efficient water allocation. An efficient water allocation is one where the marginal cost of water faced by each individual farmer is equal to the marginal cost of the district. But introducing a straightforward marginal cost pricing system would not be politically acceptable, and it has to be modified to accommodate (a) the balanced budget constraint and (b) equity considerations. Thus, the reform will result in a marginal water pricing rule with a water payment function that will depend on actual and historical rights and where aggregate revenue will be equal to aggregate costs.

Two water pricing schemes that meet the efficiency, equity, and balance budget criteria are introduced and compared. Active trading is a water trading system based on transferable water rights. Assuming that the water district has a knowledge of aggregate water demand, at the beginning of each period it purchases an optimal quantity of water (the level where aggregate demand is equal to the marginal cost). Each water user is allocated individual rights in proportion to his/her historical rights. The individuals pay for their water rights according to an average pricing rule, but then they are allowed to trade among themselves and, assuming a profit-maximizing behavior, this trading will reach an efficient outcome. The water markets in Westlands water districts can be describe to some extent as an active market since farmers have initial rights and trade among themselves.

Under passive markets, the water district establishes a water price which is equal to the opportunity cost of water and all the trading occurs between the farmers and the water districts. Each farmer is allotted an initial amount which is proportional to its historical use and pays the average cost for this amount. When farmers use more than their allotment, they will pay the marginal cost for the extra water. The district will buy the surplus water for farmers who elect to use less than their initial allotment. The passive market scheme is very similar to the buy-back program that was considered in some districts. The main advantage of the passive market over the active market is that it requires less information cost and search cost. The buyers and sellers do not have to find one another. Farmers have a ready partner for the transaction which is the district. The passive markets are especially good in regions where information costs are high and communication is difficult. The one advantage of the electronic market is the low cost of communication and transactions, and that causes this market to attain relatively low operation costs. In regions where the cost of trading among individuals are high, passive markets may be more superior.

A third alternative that aims to reach efficient resource allocation is block (tiered) pricing. In this case, farmers are charged a reduced price (may be much lower than the marginal cost of water) for an initial volume of water which is proportional to historical water uses. Any purchases above this initial level is paid according to the marginal cost of water. If farmers can trade their water, then tiered pricing will result in an efficient resource allocation. If trading is disallowed or restricted, tiered pricing may result in an inefficient resource allocation, especially when there is a significant heterogeneity among water users and some of them are very inefficient. The reason for the inefficiency is that some of the less efficient users may use all of their initial allotment that is priced far below the regional opportunity cost of water. These individuals do not allocate their water use to a point where the marginal benefits from water is equal to the regional marginal cost of water. Figure 1 illustrates this point. Consider a case where the pre-reform price was W_0. Assume that user 1 is more efficient than user 2 and both consume initially the same amount of water, Q_0, because their demand curves intersected the point where $W = W_0$. Suppose that after the reform farmers were asked to pay W_1^{ℓ} for their initial $\overline{Q}_1$ units of water and then they would have to pay W_1, the opportunity cost of water for any consumption above the initial level, $\overline{Q}_1$. User 2, the more efficient one, will use Q_2 units of water and his/her behavior will be efficient. However, in the case of user 1, he/she will use $\overline{Q}_1$ units of water, and the value of marginal product at this point will be VMP_1 which

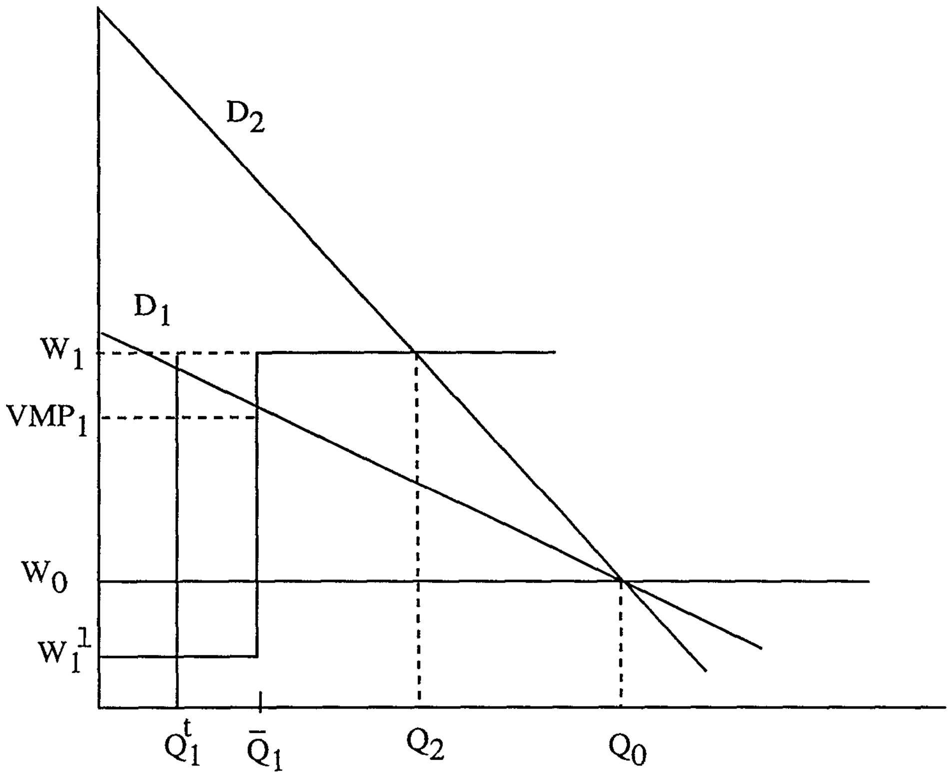

Figure 1

is below the opportunity cost of water, W_1. If User 1 would have behaved optimally, then it would have consumed Q_1 instead of $\overline{Q}_1$ and the difference between $\overline{Q}_1$ and Q_1 is the excess water causing inefficiency by user 1. Brill et al. show, using a numerical example from Israel, that the loss of efficiency associated with tiered pricing may be quite significant. In their case there was a severe overuse of irrigation water in wheat and underuse of water in higher value crops. It is very important and interesting to conduct similar analysis in California and see to what extent tiered pricing use in several water districts in California is efficient.

Emerging Markets in Water and Investments in Institutional Reform

In order to satisfy increases in water demand without investing in expensive new supply projects, western states are seeking ways to use existing water supplies more efficiently. Well-functioning markets, which enable water transfers from low- to high-valued uses, are a key to more efficient use. During the five-year drought in California between 1987 and 1992, the pressure to facilitate water transfers increased. In reaction to the drought, President Bush signed the Central Valley Project Improvement Act (CVPIA) in 1992. Among other things, the Act eliminated some of the restrictions on private water sales and reallocated 800,000 acre-feet of water annually to in-stream flows to improve water quality and protect fish habitats. The drought also triggered the development of the emergency State Water Bank in 1991 which made inter-basin water transfers possible. While developed as a temporary drought-relief measure, the Bank is now a permanent component of California water policy.

Despite these reforms, institutional barriers in the CVP still prevent many water trades from occurring and increase the cost of trades which do occur. As a result, actual water market activity is still limited. In contrast to the CVP, active water markets between agricultural and urban areas have developed in Colorado's Big Thompson Project (C-BT). There are both long-term sales of water rights and short-term water rental transactions. The allocation of water in the C-BT is governed by a different set of institutions than in the CVP which enable market transactions to occur at a lower cost. This paper compares the water allocation institutions in the CVP and C-BT and examines their effect on the organization and performance of water markets.

The analysis demonstrates the importance of institutional path dependence. While the CVP and the C-BT were contemporary projects with similar objectives, the institutions which were developed to allocate water were significantly different. The institutional choices made in the early stages of each project were constrained by pre-existing property rights systems and organizational structures. The choices were motivated by the short-term goals of building consensus between diverse interest groups and obtaining financing for construction, but they have had long-run impacts. Due to network externalities, returns to scale, and the quasi-irreversible nature of institutional investment, the organization and performance of the CVP and the C-BT today reflect the institutional paths chosen in the past.

The analysis of the CVP and C-BT is used to motivate a predictive model of institutional reform. The model demonstrates that investments in institutional reform are incremental, building from the existing set of institutions. Investments in reform can reduce the transaction costs associated with water trading, but the benefits of reform must be weighed against the costs. The costs of reform include the fixed costs of reaching a consensus among diverse interest groups and the adjustment costs associated with learning new rules and regulations. In practice, investments in reform may be delayed longer than would be predicted by traditional cost-benefit analysis. The model demonstrates that this delay is a rational response to uncertainty, irreversibility, and the ability to wait for more information.

The Effect of Water Markets on Irrigation Technology Adoption

There is extensive literature on irrigation technology adoption; however, surprisingly few studies have analyzed the effect of water markets on the adoption decision. The studies which have examined the effect of water markets do not consider the impact of dynamics or uncertainty. Farms face significant uncertainty regarding future water supplies and prices, and this uncertainty affects the value of investments in modern irrigation technology. Static models cannot capture the effect of this dynamic uncertainty on a farm's investment strategy. In addition, dynamic models which employ traditional cost-benefit analysis do not adequately account for the effect of uncertainty.

Traditional cost-benefit models of investment predict that a firm will invest when the expected present value of investment equals the cost of investment. In contrast, the model in this paper shows that, when investment is characterized by uncertainty, irreversibility, and the ability to wait for more information, farms should not invest until the expected present value of investment *exceeds* the cost of investment. This rule is more consistent with observed investment behavior. Farms require an expected return greater than the investment cost because when they invest, they give up the *option* to invest. The option to invest has a positive value because, if they wait, farms can obtain more information about future prices and supplies before committing to a sunk investment cost. Farms should not invest until the expected present value of investment equals the cost of investment *plus the value of the option to invest.*

The model assumes that the farm is currently producing with a traditional irrigation technology and it must decide when, if ever, to switch to a modern water-saving irrigation technology. The farm's decision is examined with and without the availability of a water market. When there is no market, the farm's production is a function of its stochastic water allocation. If its allocation level falls to a critical level, the farm will invest in the modern technology. When the farm has access to a water market, it can adjust its water supply in response to changes in the market price of water. If the market price is low, the farm can buy more water and, if the price is high, it can sell some of its allocation. If the price rises to a threshold level, the farm will invest in modern technology.

It is often claimed that farms will have a greater incentive to adopt modern irrigation technology if they have access to a water market. In fact, while a farm's incentive to adopt modern technology may increase, it is also possible that its incentive may decrease. Farms which might have adopted modern technology under a nonmarket water allocation system may be able to delay adoption when they have the option to buy water in a market. Therefore, it is more accurate to say that access to water markets will result in more *efficient* technology adoption, not necessarily more technology adoption. Whether a farm adopts the modern technology earlier with or without access to a water market depends on the stochastic time path of the market price and the farm's water allocation level. If water allocation is based on a priority rights system, the correlation between the market price and the farm's water allocation will depend on the relative seniority of the farm's water rights. If, for example, the farm has very senior rights, its allocation level may remain relatively constant while the market price increases over time. In this case, the farm might never adopt without market access, whereas it might adopt if it has market access. If, instead, the farm has junior rights and faces large cutbacks in its allocation relative to other water users, it might adopt earlier without market access than it would with market access.

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